

# Global energy perspectives with an emphasis on wind energy

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Chapter 4

# Global energy perspectives with an emphasis on wind energy

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This chapter gives an overview of the current status of wind power globally and the growth in installed wind capacity over the last decade. It reviews global projections of wind power growth in scenarios from various energy system models, and draws conclusions about the necessary conditions to scale-up wind energy in the future.

The future role of wind in the global energy mix was assessed from a number of energy modelling scenarios conducted by leading energy industry, research and international organizations. These include the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), the International Institute of Applied Systems Analysis (IIASA), the Global Wind Energy Council (GWEC), Exxon Mobile and the US Department of Energy (US DoE). We compare a number of global energy scenarios involving different levels of ambition for future GHG targets to see how big a role wind power is expected to play. We then showcase estimates for the future realisable global and regional potential of wind power from IRENA's recent renewable energy roadmap study (REmap) to 2030, which is based on inputs from a wide range of country experts and stakeholders.

## Global wind power: current status

Wind power installations globally have grown at around 25% a year since 2000. Wind has provided almost one third of global renewable[1] power sector capacity additions during 2001–2013 (IRENA, 2014). Global installed wind capacity at the end of 2013 was around 320 GW, including about 310 GW onshore installations (*Figure 1*). Less than 2% of current global wind capacity is installed offshore (*Figure 2*).

The regions with most installed wind capacity today are China, the US, India and Europe. These are also the regions with the fastest growth in installed capacity (*Figure 3*). Onshore wind installations were concentrated in China, followed by the EU and the US, whereas offshore wind installations were concentrated in the EU, mainly in the UK, Denmark, Germany, and Belgium.

## Wind power: Evaluating global projections towards 2050

To investigate what role wind energy can play at a global scale; we have reviewed the role of wind power in scenarios derived from global energy system models produced by leading energy industry, research and international organisations. Their various projections for wind power towards 2050 show a wide range: from a conservative 2500 TWh/y to an optimistic 14000 TWh/y. The most progressive global wind power projections discussed here are published by Greenpeace, the Global Wind Energy Council and IRENA. The most conservative global wind power projections are presented by Exxon Mobile and the US Department of Energy. *Table 1* summarises the main assumptions behind these scenarios and ranks

1. Renewable energy capacity includes wind, solar PV, solar CSP, biomass, geothermal, pumped hydro, small & large hydro.

Figure 1 - Growth of global installed wind capacity, 2000–2013 (IRENA).

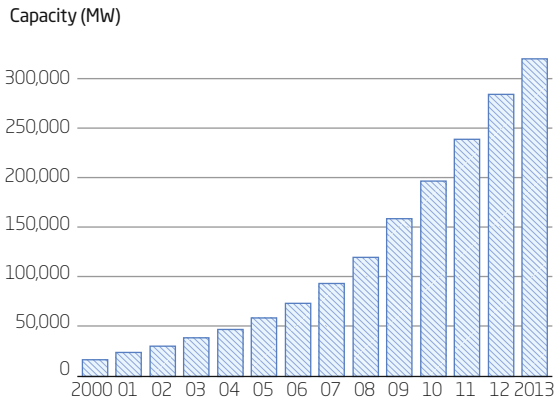



Figure 2 - Growth of global installed offshore wind capacity, 2000–2013 (IRENA).

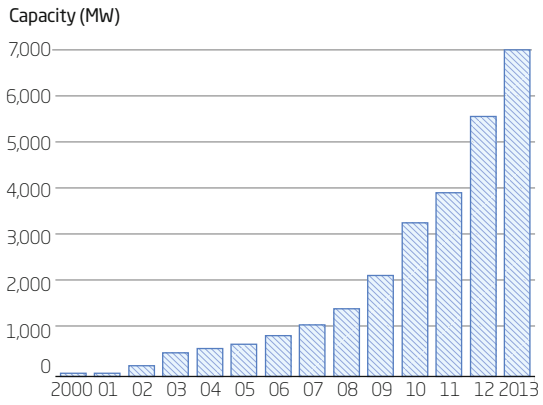
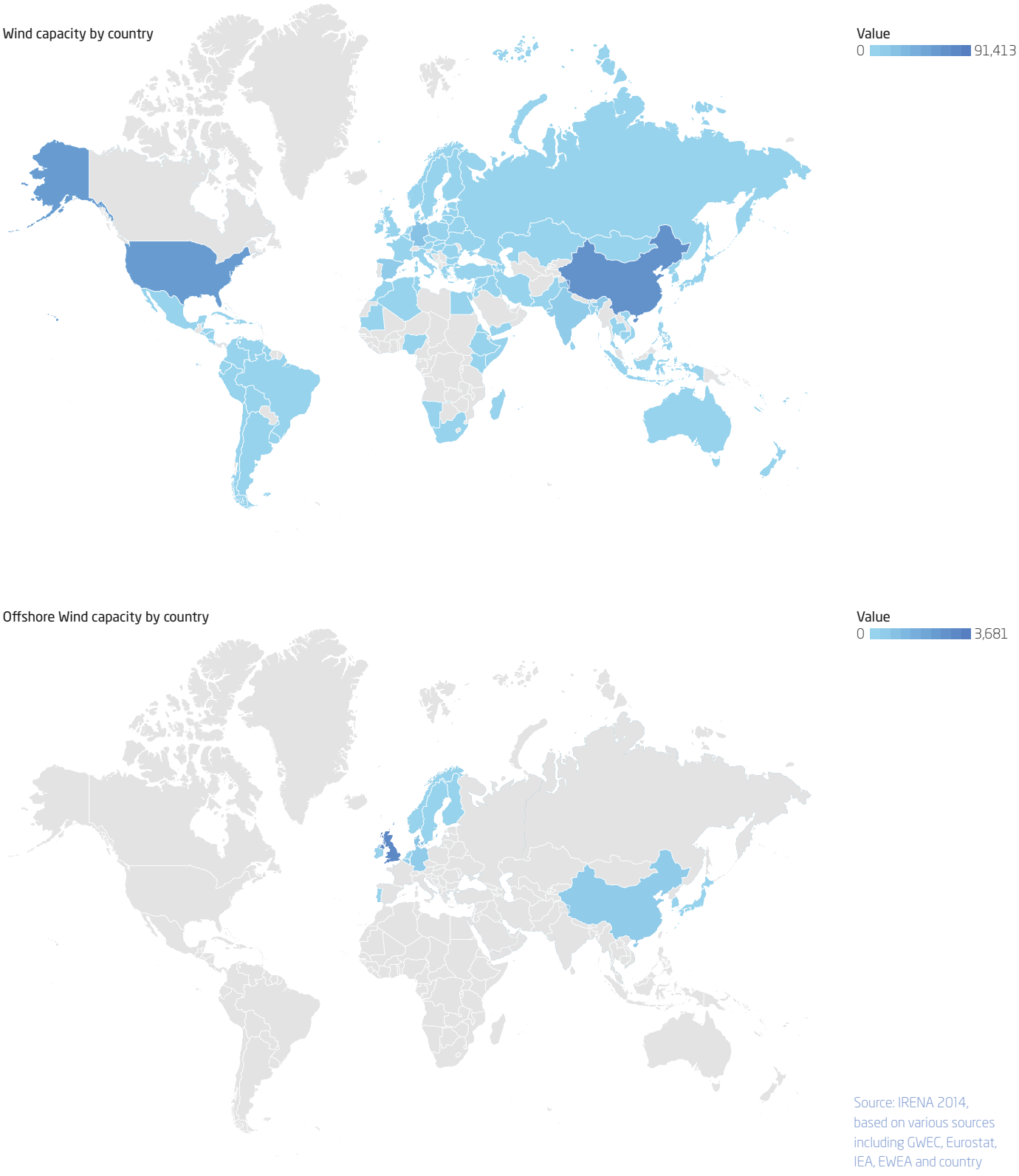


**Figure 3 -** Regional distribution of total (top) and offshore (bottom) wind capacity in 2013 (IRENA).




Source: IRENA 2014, based on various sources including GWEC, Eurostat, IEA, EWEA and country submissions

them with regard to their ambition for the role of wind power in 2050.

The institutions and organisations referred in *Table 1* often present several scenarios under different framework conditions and assumptions. Where there is a choice, we show the most ambitious GHG reduction scenarios with the most optimistic assumptions for wind power – a decision which underlines the purpose of this chapter, which is to illustrate how big a role wind power can play in the future global power system if development favours it. In order to provide a deeper understanding of an optimistic global wind power scenario, we focus more in depth on the recent IRENA renewable energy roadmap (REmap 2030) in the next paragraph.

### Wind power prospects: Insights from IRENA's renewable energy roadmap towards 2030

IRENA has developed a global renewable energy roadmap (REmap) that aims to double the share of renewables in the global energy mix by 2030. Known as REmap 2030, the roadmap was created through collaboration between IRENA, national experts within individual countries, and other stakeholders. The IRENA REmap project shows how much wind power we can expect by 2030 with the policies that have already been implemented, and what could be achieved with new policies according to the REmap 2030 roadmap. This renewable energy roadmap is based on separate assessments from each country and region, without taking global synergies into account, and is focused on achieving a doubling of renewable energy, not necessarily a lowest cost energy pathway; however it shows that in general wind power is cost-effective when compared to convention generation sources.

The aspirational target for REmap 2030 derives from the United Nations Sustainable Energy for All (SE4All) initiative. REmap 2030 is a global gap analysis built on a collective study of major energy-consuming countries. For the country analysis, existing national energy master plans, RE policy goals and targets were used to establish a reference case projecting the energy mix and power supply mix in 2030. Under this reference case, the share of renewables in world total final energy consumption would increase from 18% in 2010 (half of which is accounted for by traditional uses of biomass)

Figure 4 - Global wind generation up to 2050, as projected by seven different institutions (DTU).

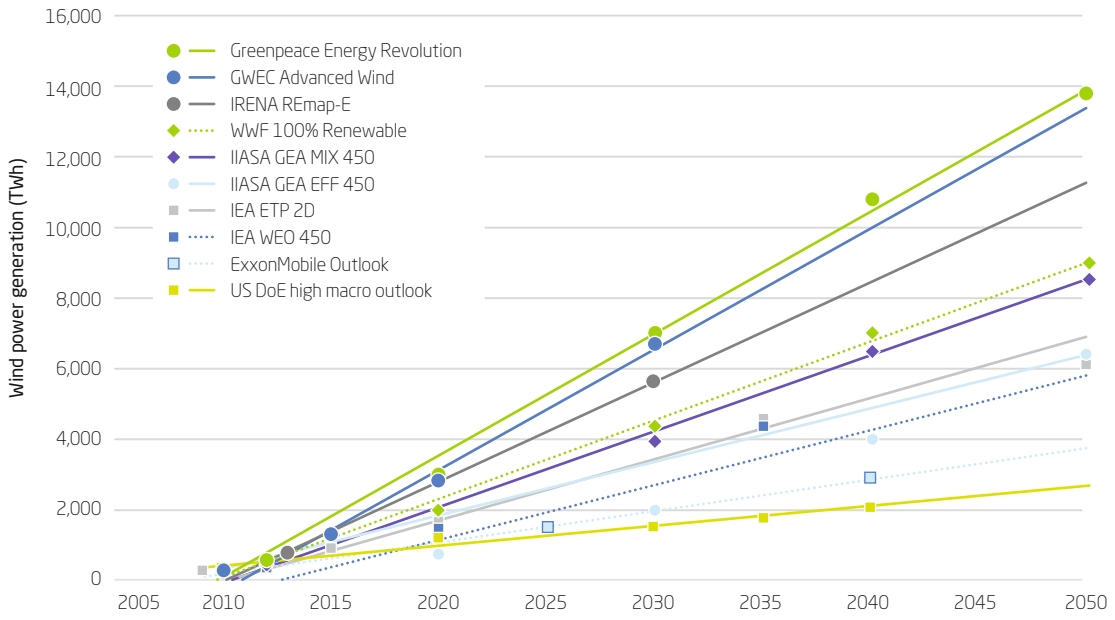
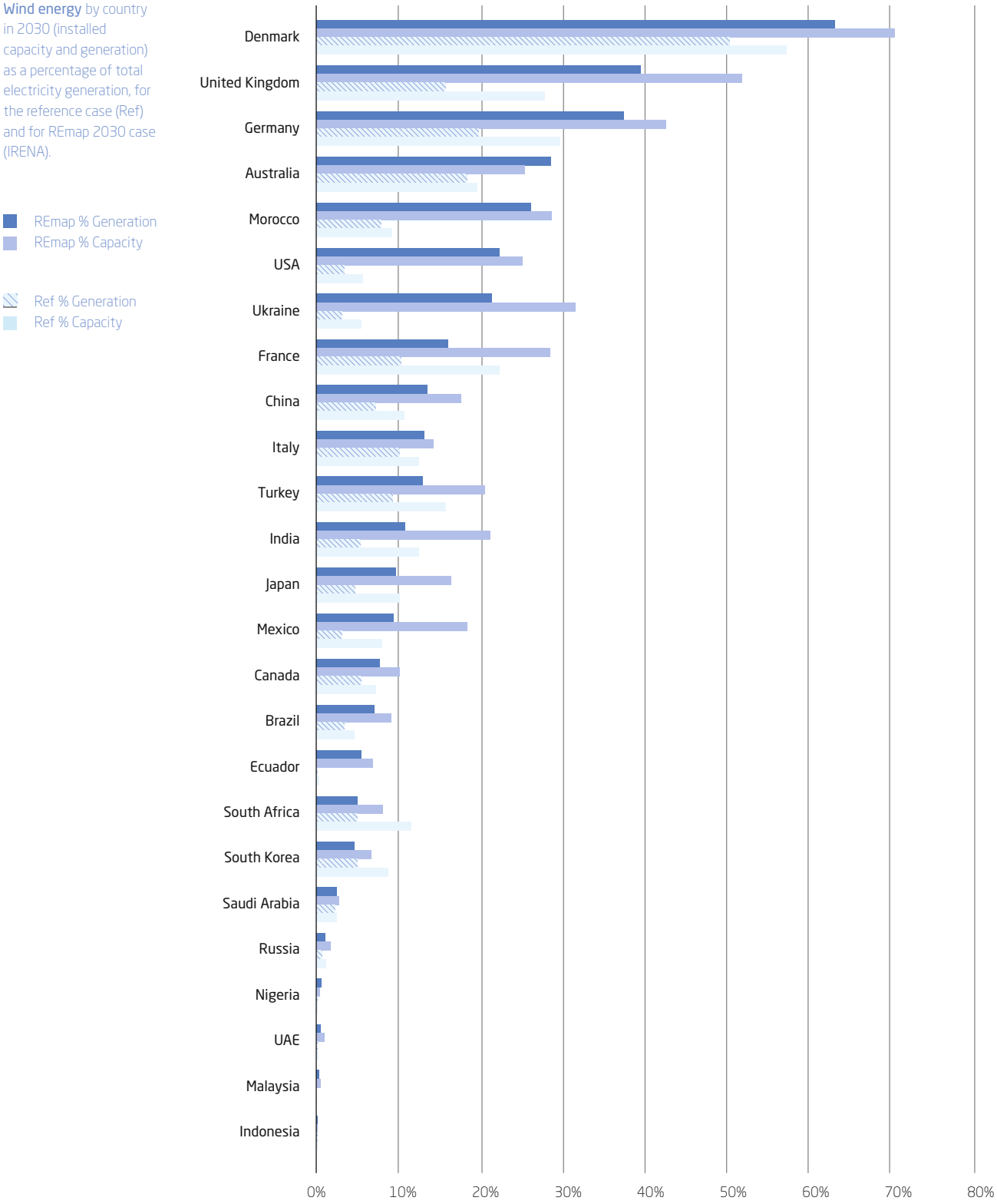


Table 1 – Global wind energy scenarios from different leading energy institutions – ranking with respect to wind power projections (DTU).

| Ranking of wind power projections | Organization; Year of Study | Main scenario assumptions |
|---|---|---|
| most progressive | Greenpeace; 2012 | Greenpeace Energy Revolution scenario<br>• goal of 100% renewable power by 2050<br>• strong political commitment and international cooperation to keep global mean temperature rise below 2°C and a carbon price of $75 /tonne<br>• hybrid/electric cars will predominate in 2050 and nuclear energy will be phased out |
| | Global Wind Energy Council (GWEC); 2013 | Advanced Wind Scenario of the Global Wind Energy Outlook<br>• electricity demand is based on the IEA's World Energy Outlook and projected to increase from 15000 TWh in 2005 to 29,000 TWh in 2030<br>• current international renewable energy and $CO_2$ targets will be met<br>• most ambitious vision to develop the full potential of global wind turbine manufacturing |
| | International Renewable Energy Agency (IRENA); 2014 | REmap-E (electrification) Case<br>• based on SE4ALL targets, country based renewable and efficiency targets, including doubling of the global renewable energy share by 2030<br>• increased electrification in energy end-use would create additional demand that would be met by mainly wind power<br>• wind capacity would increase to 2050 GW by 2030, with total production of 5600 TWh/y. The normal REmap case envisions less electrification, resulting in 1600 GW of wind capacity. |
| | World Wildlife Fund (WWF); 2011 | 100% Renewable scenario<br>• goal of 100% renewable energy by 2050<br>• final energy consumption will peak in 2020 and then decrease to 261.4 EJ in 2050, down from 327.7 EJ in 2010<br>• electrification in various sectors; in industry, the share of renewables will increase from 8% in 2010 to 79% in 2050; new buildings will be near-zero-energy by 2030; modal shift from fuel to electricity in the transport sector |
| | International Institute of Applied Systems Analysis (IIASA); 2012 | MIX 450 ppm scenario of the Global Energy Assessment<br>• scenario analysis with the bottom-up, technology-rich global MESSAGE integrated assessment model<br>• critical social and environmental goals are met, such as stabilising global mean temperature rise at 2°C, enhancing energy security through diversification of the energy supply, and attaining universal access to modern energy services by 2030<br>• primary energy demand is expected to reach 700 EJ in 2050, up from 490 EJ in 2005<br>• renewables will represent approximately 75% of primary energy by 2050<br>• Mix pathway emphasising regional diversity at an intermediate level combined with advanced transport technologies |
| | International Energy Agency; 2012 | 2 degree scenario of the Energy Technology Perspectives 2012<br>• scenario analysis with a bottom-up, technology-rich global TIMES optimisation model<br>• deployment of a low-carbon energy system, 80% chance of limiting global mean temperature rise to 2°C (consistent with IEA WEO 450 scenario)<br>• global primary energy demand will increase by 37% between 2009 and 2050<br>• oil is partially replaced by a portfolio of three alternative fuels: electricity, hydrogen and biofuels |
| | International Energy Agency; 2013 | 450 ppm $CO_2$-eq scenario of the World Energy Outlook<br>• based on the IEA's World Energy Model, which replicates the dynamics of energy markets using historical data on economic and energy variables to generate projections<br>• global primary energy demand will increase by 35% between 2010 and 2035<br>• 80% chance of limiting mean global temperature increase to 2°C |
| | International Institute of Applied Systems Analysis (IIASA); 2012 | EFF 450 ppm scenario of the Global Energy Assessment<br>• scenario analysis with the bottom-up, technology-rich global MESSAGE integrated assessment model<br>• critical social and environmental goals are met, such as stabilising global mean temperature rise at 2°C, enhancing energy security through diversification of the energy supply, and attaining universal access to modern energy services by 2030<br>• primary energy demand is expected to reach 700 EJ in 2050, up from 490 EJ in 2005<br>• renewables will represent approximately 75% of primary energy by 2050<br>• efficiency pathway emphasising demand side and efficiency improvements combined with advanced transport technologies |
| | ExxonMobil; 2014 | Global Energy Outlook<br>• scenario analysis based on Exxon Mobil Corporation's internal estimates of energy demand, supply, and trends through 2040, plus external sources including the IEA<br>• global demand for energy is projected to rise by about 35% from 2010 to 2040<br>• energy intensity will decrease by almost 45%; the share of fossil fuels in world energy demand will remain at nearly 78% |
| most conservative | US Department of Energy (US DoE); 2013 | High macro scenario of the International Energy Outlook<br>• projections are generated from the EIA's World Energy Projection Plus (WEPS+) model<br>• high macro-economic growth globally: 3.4% annually on average from 2008 to 2035<br>• world total energy consumption will increase by 53% from 2008 to 2035<br>• energy intensity will decline by just under 40% from the 2008 level; the price of oil is $125 per barrel in 2035; electricity generation will increase by nearly 84% |

## Figure 5 - Wind energy by country in 2030.

**Wind energy** by country in 2030 (installed capacity and generation) as a percentage of total electricity generation, for the reference case (Ref) and for REmap 2030 case (IRENA).



to 21% in 2030. Government-nominated country experts (REmap experts) and IRENA subject experts then identified additional technology options for deploying renewable energy beyond the reference case, and assessed their cost implications.

REmap explore ddifferent renewable energy deployment options with varying level of ambitions, leading to higher shares than the reference case. Up to 36% of renewable energy, measured in terms of the share in total final energy consumption (TFEC) is projected for 2030 when renewable energy deployment is combined with universal energy access and improved energy efficiency. Under the REmap case, the potential to deploy an additional 660 GW of wind capacity above the reference case was identified, producing 4400 TWh/y from 1630 GW of total capacity by 2030. Wind energy becomes the fourth-largest source of power after coal, natural gas and hydro, and the third-largest renewable energy source (if viewed in final energy terms, which include the share of renewables in the electricity consumption in the end-use sectors) in 2030 after biomass and hydro power. REmap also explored another deployment option in which increased electrification in energy end-use would create additional demand that would be met by renewable power, mainly wind power. This "REmap-E" case would increase wind capacity to 2050 GW, with total production of 5600 TWh/y by 2030. The study shows that the country with the largest expected share of wind energy in its power system in 2030 is Denmark (with over 60% of its electricity from wind), followed by Germany and the UK (40–50%). Further down the league are Australia, France and the US (20%), and then a group that includes China (15–20%).

### Conclusion: Enabling conditions for scaling-up global wind power

The future role of wind power on a global scale is set to increase further. The level of ambition towards wind electricity generation depends however on many factors and projections from the discussed studies vary considerably. The most optimistic studies for wind energy are based on a strong political commitment for a future low-carbon energy system and assume a global energy transition towards keeping global mean temperature rise below 2°C by 2050.

Progressive wind energy projections assume an installed wind capacity of up to 5000 GW in 2050. This assumes that about 4600 GW wind installations (more than 14 times of the current level) would need to be manufactured, installed and grid-connected globally. Such an expansion of global wind capacity would mean that the wind turbine manufacturing industry would have to be able to build and install about 100 GW/year in 2020, and 200–250 GW/year from 2030 onwards when assuming a 20-year turbine life. The geographical patterns of onshore and offshore wind deployment are projected to diversify, based on country-specific conditions. Considerable additional investments in wind power are needed to implement any ambitious renewable energy scenario. Reaching the wind capacities identified in REmap 2030 would for example require annual investments of $314 billion/y for onshore wind and $47 billion/y for offshore wind.

In summary we identify the following enabling key factors to scale-up wind energy in the future:

- Flexible electricity demand and transition to electricity-based energy systems, for example by increased electrification of the transport sector
- power systems, that are able to handle increasingly higher shares of intermittent power production, such as shown in Denmark
- progressive cost reduction of wind power technologies
- continuous high investments in wind energy, that allow manufacturing and installation of about 100 GW/year globally